DESIGNERS' CHARTS FOR REINFORCED CONCRETE

JOINT COMMITTEE STANDARDS

THE DESIGN OF
REINFORCED CONCRETE SLABS BEAMS AND COLUMNS

CONFORMING TO THE RECOMMENDATIONS OF THE

JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE

COMPOSED OF COMMITTEES OF THE

American Society of Civil Engineers American Society for Testing Materials
American Railway Engineering and Maintenance of Way Association
Association of American Portland Cement Manufacturers

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PREFACE

The need of standard methods for designing reinforced concrete has long been felt, as there has been heretofore little unity in practice.

It is the purpose of this pamphlet with its accompanying charts to present standard reinforced concrete sections based on the most authentic data, in a simple form, so that any designer, whether entirely conversant with reinforced concrete or not, will not go astray in his calculations.

From 1899 to 1904 committees from the societies named on the title page were appointed to study the subject of concrete and reinforced concrete. In June, 1904, these several committees consolidated, and since that time have been preparing a report on the subject. This report of the joint committee was presented at the January, 1909, meeting of the American Society of Civil Engineers and ordered published in their proceedings. The Joint Committee was composed of thirty members and the report was signed by twenty-four of the thirty. It is thus the most authoritative treatise on concrete presented to the public, and therefore warrants its careful consideration.

The texts and charts herein conform as closely as possible to the recommendations embodied in the report of the Joint Committee and the calculations have been verified by Sanford E. Thompson, Member American Society of Civil Engineers, a member of the committee, to whose valued assistance the author is very much indebted.

H. B. ANDREWS.

GENERAL RECOMMENDATIONS*

Rules for structures of reinforced concrete for the purpose of fixing the responsibility and providing for adequate supervision during construction

a. Before work is commenced, complete plans should be prepared, accompanied by specifications, static computations and descriptions showing the general arrangement in all details. The static computations shall give loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

b. The specifications shall state the qualities of the materials to be used for making the concrete, and the proportions in which they are to be mixed.

c. The strength which the concrete is expected to obtain after a definite period shall be stated in the specifications.

d. The drawings and specifications shall be signed by the engineer and contractor.

e. The approval of the plans and specifications by the other authorities shall not relieve the engineer nor the contractor of responsibility.

f. Inspection during construction shall be made by competent inspectors employed by, and under the supervision of the engineer, and shall cover the following:

1. The materials.
2. The correct construction and erection of the forms and supports.
3. The sizes, shapes and arrangement of the reinforcement.
4. The proportioning, mixing and placing of the concrete.
5. The strength of the concrete by tests of standard test pieces made on the work.
6. Whether the concrete is sufficiently hardened before the forms and supports are removed.
7. Prevention of injury to any part of the structure by and after the removal of the forms.
8. Comparison of dimensions of all parts of the finished structure with the plans.

g. Load tests on portions of the finished structure shall be made where there is reasonable suspicion that the work has not been properly performed, or that, through influences of some kind, the strength has been impaired. Loading shall be carried to such a point that twice the calculated working stresses in critical parts are reached, and such loads shall cause no permanent deformations. Load tests shall not be made until after sixty days of hardening.

Materials

Cement.—The cement shall meet the requirements of the standard specifications for cement adopted August 15, 1908, by the American Society for Testing Materials.

Aggregate.—Extreme care should be exercised in selecting the aggregates for mortar and concrete, and careful tests made of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density or a minimum percentage of voids.

Fine Aggregate.—*a.* Fine aggregate consists of sand, crushed stone or gravel screenings, passing, when dry, a screen having one quarter inch diameter holes.

It should be preferably of siliceous material, clean, coarse, free from vegetable loam or other deleterious matter, and not more than six per cent should pass a sieve having one hundred meshes per linear inch.

*Quoted direct from Joint Committee Report.

A gradation of the grain from fine to coarse is generally advantageous.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least seventy per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

Coarse Aggregate.—*b.* Coarse aggregate consists of inert material, such as crushed stone or gravel, which is retained on a screen having one quarter inch diameter holes. The particles should be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles should be excluded from important structures.

A gradation of sizes of the particles is generally advantageous.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms.

Where concrete is used in mass the size of the coarse aggregate may be such as to pass a three-inch ring. For reinforced members a size to pass a one-inch ring is a customary maximum.

Cinder Concrete.—Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fire-proofing. Where cinder concrete is permissible, the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

Water.—The water used in mixing concrete should be free from oil, acid, strong alkalies or vegetable matter.

Metal Reinforcement.—The committee recommends as a suitable material for reinforcement steel filling the requirements of the specifications adopted by the American Railway Engineering and Maintenance of Way Association.

For the reinforcement of slabs, small beams, or minor details, or for the prevention of shrinkage cracks, or where wire or small rods are suitable, material conforming to the requirements of either specification "A" or "B" may be used.

The reinforcement should be free from rust, scale, or coatings of any character which would tend to reduce or destroy the bond.

Preparation and Placing of Mortar and Concrete

Proportions.—The material to be used in concrete should be carefully selected, of uniform quality, and proportioned with a view of securing as nearly as possible a maximum density.

Unit of Measure.—*a.* The unit of measure should be the barrel, which should be taken as containing 3.8 cubic feet. Four bags containing ninety-four pounds of cement each should be considered the equivalent of one barrel.

Fine and coarse aggregate should be measured separately as loosely thrown in to the measuring receptacle.

Relation of Fine and Coarse Aggregate.—*b.* The fine and coarse aggregate should be used in such relative proportions as will insure maximum density. In unimportant work it is sufficient to do this by individual judgment, using correspondingly higher proportions of cement; for important work these proportions should be carefully determined by density experiments and the sizing of the fine and coarse aggregates maintained uniform or the proportions changed to meet the varying sizes.

Relation of Cement and Aggregate.—*c.* For reinforced concrete construction a density proportion based on 1:6 should generally be used, *i.e.*, one part of cement to a total of six parts of fine and coarse aggregates measured separately. In columns richer mixtures are often required, while for massive masonry or rubble concrete a

leaner mixture of 1:9 or even 1:12 may be used. These proportions should be determined by the strength or wearing qualities required in the construction at the critical period of its use. Experienced judgment based on individual observation and tests of similar conditions in similar localities is the best guide as to the proper proportions for any particular case.

Mixing.—The ingredients of concrete should be thoroughly mixed to the desired consistency and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

Measuring Proportions.—*a.* Methods of measurement of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

Machine Mixing.—*b.* When the conditions will permit, a machine mixer of a type which insures the proper proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

Hand Mixing.—*c.* When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color.

Consistency.—*d.* The materials should be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

Retempering.—*e.* Retempering mortar or concrete, *i.e.*, remixing with water after it has partially set, should not be permitted.

Placing of Concrete

Methods.—*a.* Concrete, after the addition of water to the mix, should be handled rapidly, and in as small masses as is practicable, from a place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is liable to occur between mixing and final placing.

The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

In depositing the concrete under water, special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance, which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from débris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

When work is resumed, concrete previously placed should be roughened, thoroughly cleansed from foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate. The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

Freezing Weather.—*b.* The concrete for reinforced structures should not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and providing means to prevent the concrete

from freezing after being placed in position and until it has thoroughly hardened.

Rubble Concrete.—*c.* Where the concrete is to be deposited in massive work, its value may be improved and its cost materially reduced through the use of clean stones thoroughly imbedded in the concrete as near together as is possible and still entirely surrounded by concrete.

Forms

Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight, to prevent the leakage of mortar.

The time for removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete.

Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

So many conditions affect the hardening of concrete, that the proper time for the removal of forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavorable.

Details of Construction

Joints; Reinforcement.—Wherever in tension reinforcement it is necessary to splice the reinforcing bars, the length of lap shall be determined on the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at points of maximum stress should be avoided. In columns large bars should be butted and spliced; small bars may be treated as indicated for tension reinforcement or their stress may be taken off by being imbedded in large masses of concrete. At foundations, bearing plates should be provided for large bars or structural forms.

Concrete.—For concrete construction it is desirable to cast the entire structure at one operation, but as this is not always possible, especially in large structures, it is necessary to stop the work at some convenient point. This point should be selected so that the resulting joint may have the least possible effect on the strength of the structure.

It is therefore recommended that the joint in columns be made flush with the lower side of the girders; that the joints in girders be at a point midway between supports, but should a beam intersect a girder at this point, the joint should be offset a distance equal to twice the width of the beam; that the joints in the members of a floor system should in general be made at or near the center of the span.

Joints in columns should be perpendicular to the axis of the column, and in girders, beams and floor slabs perpendicular to the plane of their surfaces.

Shrinkage.—Girders should never be constructed over freshly formed columns without permitting a period of at least two hours to elapse, thus providing for settlement or shrinkage in the columns. Before resuming work, the top of the column should be thoroughly cleansed of foreign matter and laitance. If the concrete in the column has become hard the top should also be drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate before placing additional concrete.

Temperature Changes.—Concrete is sensitive to temperature changes and it is necessary to take this fact into account in designing and erecting concrete structures. In some positions the concrete is subjected to a much greater fluctuation in temperature than in others, and in such cases joints are necessary. The frequency of these joints will depend, first, upon the range of temperature to which the concrete will be subjected; second, upon the quantity and position of the reinforcement.

These points should be determined and provided for in the design.

In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints should be provided, approximately, every fifty feet throughout the length of the structure. To provide against the structures being thrown out of line by unequal settlement, each section of the wall may be tongued and grooved into the adjoining section.

To provide against unsightly cracks, due to unequal settlement, a joint should be made at all sharp angles.

Fire-proofing.—It is recommended that in monolithic concrete columns, the concrete to a depth of one and one half inches be considered as protective covering and not included in the effective section.

For ordinary conditions it is recommended that the metal in girders and columns be protected by a minimum of two inches of concrete; that the metal in beams be protected by a minimum of one and one half inches of concrete, and that the metal in floor slabs be protected by a minimum of one inch of concrete.

It is recommended that the corners of columns, girders and beams be beveled or rounded, as a sharp corner is more seriously affected by fire than a round one.

General Assumptions for Loads

Loads.—The loads or forces to be resisted consist of:—

1. The dead load, which includes the weight of the structure and fixed loads and forces.

2. The live load, or the loads and forces which are variable. The dynamic effect of the live load will often require consideration. Any allowance for the dynamic effect is preferably taken into account by adding the desired amount to the live load or to the live load stresses.

The working stresses hereinafter recommended are intended to apply to the equivalent static stresses so determined.

In the case of high buildings the live load on columns may be reduced in accordance with the usual practice.

Reinforced Concrete Slabs

Span.—The span length for slabs shall be taken as the distance from center to center of supports, but shall not exceed the clear span plus the depth of slab.

Reinforcement.—Floor slabs shall be designed and reinforced as continuous over intermediate supports. The chart takes into consideration reinforcement in one direction only. Reinforcement shall be fully provided at points of negative moment.

In computing the positive and negative moments in slabs continuous over several supports due to uniformly distributed loads, the following rules are given:—

1. That for floor slabs, the bending moment at center and at support be taken at $wl^2 \div 12$ for both dead and live loads where w represents the load per linear foot and l the span length.

2. That for floor slabs over one or two bays only, the bending moment shall be taken at $wl^2 \div 10$ for both dead and live loads.

3. Special consideration is required in the case of concentrated loads.

4. Reinforcement is to be lapped a sufficient distance over supports to provide adequate bond strength.

5. The center of slab reinforcement shall be one inch above bottom of slab at middle of span, and one inch from top of slab over supports.

Working Stresses.—The extreme fiber stress of a slab may be allowed to reach 650 pounds per square inch for 1:2:4 concrete, conforming to Joint Committee requirements, under assumed working loads.

The tensile strength in steel may be allowed to reach 16,000 pounds per square inch under assumed working loads.

Reinforced Concrete Beams

Span.—The span length for beams shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam.

T-Beams. — In beam and slab construction an effective bond shall be provided at the junction of beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement shall be used extending over the beam and well into the slab.

Where adequate bond between the slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width shall be determined by the following rules: —

a. It shall not exceed one fourth of the span length of the beam;

b. Its overhanging width on either side of the web shall not exceed four times the thickness of the slab.

(Note. — Where the width of slab does not equal the effective width allowed by these rules, special consideration must be given to make assurance that the concrete in slab is not overstressed in compression.)

c. In the designs of T-beams acting as continuous beams, due consideration shall be given to the compressive stresses at the supports.

Reinforcement. — Beams shall be designed and reinforced as continuous over intermediate supports. Reinforcement shall be fully provided at points of negative moment.

In computing the positive and negative moments, in beams and slabs continuous over several supports, due to uniformly distributed loads, the following rule is given:—

That for beams the bending moment at center and at supports for interior spans be taken at $wl^2 \div 12$, and for end spans it be taken as $wl^2 \div 10$ for center and adjoining support for dead and live loads.

In the case of beams continuous for two spans only, more exact calculations should be made. Special consideration is also required in the case of concentrated loads.

Where beams are reinforced on the compressive side, the steel may be assumed to carry its proportion of the stress.

In the case of continuous beams, tensile and compressive reinforcement must extend sufficiently beyond the support to develop the requisite bond stress.

Bond Strength and Spacing of Bars. — Adequate bond strength should be provided in accordance with the formula hereinafter given. Where a portion of the bars is bent up near the end of a beam, the bond stress in the remaining straight bars will be less than is represented by the theoretical formula.

Where high bond resistance is required, the deformed bar is a suitable means of supplying the necessary strength. Adequate bond strength throughout the length of a bar is preferable to end anchorage, but such anchorage may be properly used in special cases. Anchorage furnished by short bends at a right angle is less effective than hooks consisting of turns through 180 degrees.

The lateral spacing of parallel bars should not be less than two and one half diameters, center to center, nor should the distance from the side of the beam to the center of the nearest bar be less than two diameters.

The clear spacing between two layers of bars should not be less than one half inch.

Shear and Diagonal Tension. — Calculations for web resistance shall be made on the basis of maximum shearing stress, as determined by the formulas hereinafter given. When the maximum shearing stresses exceed the value allowed for the concrete alone, web reinforcement must be provided to carry the diagonal tension stresses. This web reinforcement may consist of bent bars, or inclined or vertical members attached to or looped about the horizontal reinforcement. Where inclined members are used, the connection to the horizontal reinforcement shall be such as to insure against slip.

The following allowable values for the maximum shearing stress are recommended: —

a. For beams with horizontal bars only 40 pounds per square inch.

b. For beams in which a part of the horizontal reinforcement is used in the form of bent-up bars, arranged with due respect to the shearing stresses, a higher value may be allowed, but not exceed 60 pounds per square inch.

c. For beams thoroughly reinforced for shear a value not exceeding 120 pounds per square inch.

In the calculation of web reinforcement to provide the strength required under *c* above, the concrete may be counted upon as carrying one third of the shear. The remainder is to be provided for by means of metal reinforcement, consisting of bent bars or stirrups, but preferably both. The requisite amount of such reinforcement may be estimated on the assumption that the entire shear on a section, less the amount assumed to be carried by the concrete, is carried by the reinforcement in a length of beam equal to its depth.

The longitudinal spacing of stirrups or bent rods shall not exceed three fourths the depth of the beam.

It is important that adequate bond strength be provided to fully develop the assumed strength of all shear reinforcement.

Inasmuch as small deformations in the horizontal reinforcement tend to prevent the formation of diagonal cracks, a beam will be strengthened against diagonal tension failure by so arranging the horizontal reinforcement that the unit stresses at points of large shear shall be relatively low.

Working Stresses. — The extreme fiber stress of a beam may be allowed to reach 650 pounds per square inch for 1: 2: 4 concrete conforming to Joint Committee requirements, under assumed working loads. Adjacent to the support of continuous beams 750 pounds per square inch may be used.

The tensile stress in steel may be allowed to reach 16,000 pounds per square inch, and the compressive stress in steel at supports 11,250 pounds per square inch in 1: 2: 4 concrete.

For working stresses for bond, shear and diagonal tension see page 10.

Columns

Length. — The ratio of unsupported length to the least width of any column shall be limited to 10.

Effective Area. — This shall be taken as the area within the protective covering. Or in the case of hooped columns or columns reinforced with structural shapes, it shall be taken as the area within the hooping or structural shapes.

Reinforcement. — Columns may be reinforced with longitudinal bars by bands or hoops together with longitudinal bars, or by means of structural forms which in themselves are sufficiently rigid to act as columns.

Bars composing longitudinal reinforcement shall be straight, and shall have sufficient lateral support to be securely held in place until the concrete is set.

Where bands or hoops are used, the total amount of such reinforcement shall be not less than one per cent of the volume of concrete enclosed.

The clear spacing of such bands or hoops shall be not greater than one fourth the diameter of the enclosed column. Adequate means must be provided to hold the bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the value above specified.

Working Stresses. — 1. For plain concrete columns, or for columns with longitudinal reinforcement only, 450 pounds per square inch for 1:2:4 concrete, and 562.5 pounds per square inch for 1:1½:3 concrete, conforming to Joint Committee requirements. (Described as "A" on chart.)

2. For columns reinforced with bands or hoops, 540 pounds per square inch for 1:2:4 concrete, and 675 pounds per square inch for 1:1½:3 concrete. (Described as "B" on chart.)

3. For columns reinforced with not less than 1 per cent and not more than 4 per cent of longitudinal bars and with bands or hoops, 640 pounds per square inch for 1:2:4 concrete and 800 pounds per square inch for 1:1½:3 concrete. (Described as "C" on chart.)

4. For columns reinforced with structural steel column units which thoroughly encase the concrete core, the same stresses as given for 3.

5. For longitudinal reinforcement, not less than 1 per cent, and not over 4 per cent of the effective area of the concrete, 15 times the unit stress allowed in the concrete may be used.

Fire-proofing. — Concrete to the depth of 1½ inches shall be considered as protective covering and not included in the effective section.

Working Stresses

The stresses for concrete hereinafter given are for concrete composed of one part Portland cement and six parts of aggregate capable of developing an average compressive strength of 2000 pounds per square inch at 28 days, when tested in cylinders 8 inches in diameter and 16 inches long, under laboratory conditions of manufacture and storage, using the same consistency as used in the field. If the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

Bearing. — When compression is applied to a surface of concrete larger than the load area, 650 pounds per square inch may be allowed.

Axial Compression. — For concentric compression on a plain column or pier, the length of which does not exceed 12 diameters, 450 pounds per square inch may be allowed.

Compression in Extreme Fiber. — The extreme fiber stress of a beam may be allowed to reach 650 pounds per square inch. Adjacent to the support of continuous beams 750 pounds per square inch may be allowed.

Shear and Diagonal Tension. — When pure shearing stress occurs, 120 pounds per square inch may be allowed.

Where the shear is combined with an equal compression, as on a section of column at 45 degrees with the axis, the stress may equal one half the compressive stress allowed.

In calculations on beams in which diagonal tension is considered to be taken by the concrete, the vertical shearing stresses should not exceed 40 pounds per square inch.

Bond. — The bonding stress between concrete and plain reinforcing bars may be assumed at 80 pounds per square inch, and in the case of drawn wire 40 pounds per square inch.

Reinforcement. — The tensile strength in steel should not exceed 16,000 pounds per square inch. The compressive stress in reinforcing steel should not exceed 16,000 pounds per square inch, or 15 times the working compressive stress in the concrete.

Formulas

Rectangular beams or unit widths of slabs

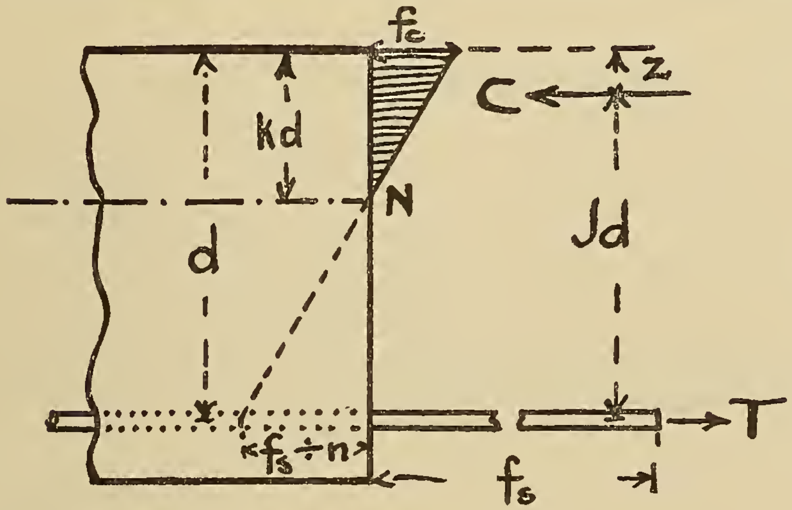


Fig. 1

Standard Notation.

f_s = tensile unit stress in steel
f_c = compressive unit stress in concrete
N = ratio of modulus of elasticity of steel to modulus of concrete
M = moment of resistance or bending moment in general
b = breadth of beam
d = depth of beam to center of steel
k = ratio of depth of neutral axis to depth of beam, d
p = ratio of area of steel to area of concrete

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn = .38$$

Arm of resisting couple,

$j = 1 - \frac{1}{3}k$ or $\frac{7}{8}$, very approximately

Fiber stresses,

$f_s = 16{,}000$
$f_c = 650$

Steel ratio,

$$p = \frac{1}{2} \cdot \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c} + 1\right)} = .0077$$

Area of steel,

$A_s = .0077\ bd$

Moment of resistance,

$M = f_s\ .0077\ bd \times \frac{7}{8}\ d$

T-Beams

Continuous beams reinforced for compression at supports as shown by Fig. 2.

The position of the neutral axis and arm of resisting couple are in practically the same location as in rectangular beams.

Fiber stresses,

$f_s = 16000$ (steel in tension)
$f_{s1} = 11250$ (steel in compression)
$f_c = 650$ (concrete in compression at top of beam)
$f_{c1} = 750$ (concrete in compression at supports)

Steel ratio assumed,

$p = .016$

Area of steel,

$A_s = .016\ bd \left(\text{when } M = \frac{wl^2}{12}\right)$

For end spans and spans over two bays only,

$p = .0192$

Area of steel,

$A_s = .0192\ bd \left(\text{when } M = \frac{wl^2}{10}\right)$

Moments of resistance,

$M = f_s\ .016\ bd \times \frac{7}{8}\ d$
$M = f_s\ .0192\ bd \times \frac{7}{8}\ d$

Formulas

Beams or unit widths of slabs

Shear, bond and web reinforcement,

V = total shear

v = shearing unit stress

u = bond stress per unit area of bar

o = circumference or perimeter of bar

Σo = sum of the perimeters of all bars

In the following formulas Σo refers only to the bars constituting the tension reinforcement at the section in question and jd is the lever arm of the resisting couple at the section.

For rectangular beams,

$$v = \frac{V}{bjd}$$

$$u = \frac{V}{jd.\Sigma o}$$

(For practical results j may be taken at ⅞.)

The stresses in web reinforcement may be estimated by means of the follow ing formulas:—

Vertical reinforcement,

$$f_s = \frac{Vs}{jd}$$

Reinforcement inclined at 45 degrees,

$$f_s = 0.7\frac{Vs}{jd}$$

in which

f_s = stress in single reinforcing member

V = proportion of total shear assumed as carried by the reinforcement

and s = horizontal spacing of the reinforcing members

The same formulas apply to beams reinforced for compression as regards shear and bond stress for tensile steel.

For T-beams,

$$v = \frac{V}{b'\,jd}$$

$$u = \frac{V}{jd.\Sigma o}$$

(For approximate results j may be taken at ⅞.)

Columns,

A = total net area

A_s = area of longitudinal steel

A_c = area of concrete

W = total safe load

p = ratio of area of steel to area of effective section

Total safe load,

$$W = f_c\,(A_c + nA_s) = f_cA\,[1 + (n-1)\,p]$$

Unit stresses,

$$f_c = \frac{p}{A\,[1 + (n-1)\,p]}$$

$$f_s = nf_c$$

Spacing and Sectional Area of Reinforcement for Slabs One Foot in Width

	STEEL RODS																	WIRE. (W. & M.)					EXPANDED METAL		
SIZE	4″	4½″	5″	5½″	6″	6½″	7″	7½″	8″	8½″	9″	9½″	10″	10½″	11″	11½″	12″	GA.	SEC.	2″	3″	4″	MESH.	GA.	Designated
5-16″ Ro.	.230	.205	.184	.167	.153	.141	.131	.123	.115	.108	.102	.097	.092	.088	.084	.080	.077	No. 0	.074	.443	.295	.221	1-2″	No. 18	Stand.
Sq.	.292	.260	.234	.213	.195	.180	.167	.156	.146	.137	.130	.123	.117	.111	.106	.102	.098	1	.061	.368	.245	.184	3-4″	13	"
3-8″ Ro.	.331	.294	.265	.241	.221	.204	.189	.177	.166	.156	.147	.139	.132	.126	.120	.115	.110	2	.054	.325	.216	.162	1 1-2″	12	"
Sq.	.422	.375	.337	.307	.281	.260	.241	.225	.211	.198	.187	.178	.169	.161	.154	.147	.141	3	.047	.280	.187	.140	2″	12	"
7-16″ Ro.	.451	.401	.361	.328	.301	.277	.258	.240	.225	.212	.200	.190	.180	.173	.164	.156	.150	4	.040	.239	.160	.120	3″	16	"
Sq.	.574	.510	.459	.418	.383	.353	.328	.306	.287	.270	.255	.241	.230	.219	.209	.199	.191	5	.033	.201	.134	.101	3″	10	Light
1-2″ Ro.	.589	.523	.471	.428	.393	.362	.336	.314	.294	.277	.262	.248	.236	.225	.214	.204	.196	6	.029	.174	.116	.087	3″	10	Stand.
Sq.	.750	.667	.600	.545	.500	.462	.429	.400	.375	.353	.333	.316	.300	.286	.273	.261	.250	7	.025	.148	.098	.074	3″	10	Heavy
9-16″ Ro.	.745	.663	.596	.542	.497	.459	.426	.398	.373	.351	.331	.314	.298	.284	.271	.259	.248	8	.021	.124	.083	.062	3″	10	Ex. Heavy
Sq.	.949	.844	.759	.690	.632	.584	.542	.506	.475	.447	.422	.400	.380	.362	.345	.330	.316						3″	6	Stand.
5-8″ Ro.	.920	.818	.736	.669	.614	.566	.526	.491	.460	.433	.409	.387	.368	.351	.335	.320	.307						3″	6	Heavy
Sq.	1.172	1.042	.937	.852	.781	.721	.670	.625	.586	.551	.521	.493	.469	.446	.426	.408	.391						4″	16	Old Style
11-16″ Ro.	1.114	.990	.891	.810	.742	.685	.636	.594	.557	.524	.495	.469	.445	.424	.405	.387	.371						6″	4	Stand.
Sq.	1.418	1.261	1.134	1.031	.945	.873	.810	.756	.709	.668	.630	.597	.567	.540	.516	.494	.473						6″	4	Heavy
3-4″ Ro.	1.325	1.178	1.060	.964	.884	.816	.757	.707	.663	.624	.589	.558	.530	.506	.482	.461	.442								
Sq.	1.687	1.500	1.350	1.227	1.125	1.038	.964	.900	.844	.794	.750	.711	.675	.642	.613	.606	.562								

Weights and Areas of Steel Rods for Beam Reinforcement

SIZE	AREA SQ.	WT. SQ.	AREA RO.	WT. RO.
7-16″........	.191	.651	.150	.511
1-2″........	.250	.850	.196	.667
5-8″........	.391	1.328	.307	1.043
3-4″........	.562	1.913	.442	1.502
7-8″........	.766	2.603	.601	2.044
1″............	1.000	3.400	.785	2.670
1 1-8″........	1.266	4.303	.994	3.379
1 1-4″........	1.562	5.312	1.227	4.173
3-16″x3-4″....	.141	.479		
3-16″x1″......	.187	.637		
3-16″x1 1-4″..	.234	.796		

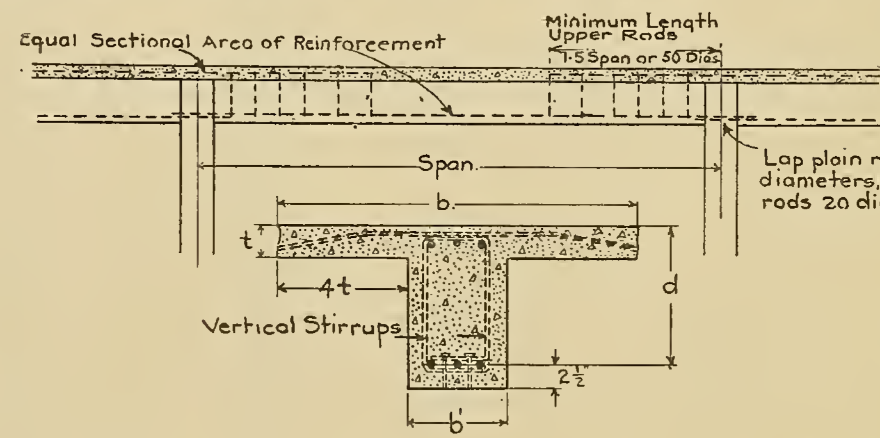


Fig. 2

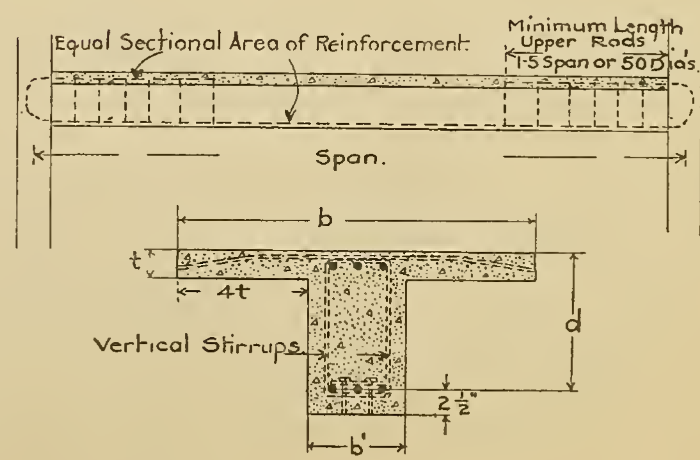


Fig. 3

TYPICAL BEAM REINFORCEMENT

NOTE.—One half of the tension rods may be trussed over supports.

Number of Rods and Sectional Area in Square Inches for Column Reinforcement

SIZE OF ROD		4	5	6	7	8	9	10	11	12	13	14	15	16
3-4"	dia.	1.77	2.25	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74	6.18	6.63	7.07
	sq.	2.25	2.81	3.38	3.94	4.50	5.06	5.62	6.18	6.75	7.31	7.88	8.44	9.00
7-8"	dia.	2.41	3.01	3.61	4.21	4.81	5.41	6.01	6.61	7.22	7.82	8.42	9.02	9.62
	sq.	3.06	3.83	4.59	5.36	6.12	6.89	7.65	8.42	9.18	9.95	10.71	11.48	12.24
1"	dia.	3.14	3.93	4.71	5.50	6.28	7.07	7.85	8.64	9.42	9.95	11.00	11.78	12.57
	sq.	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
1 1-8"	dia.	3.98	4.97	5.97	6.96	7.96	8.95	9.95	10.94	11.94	12.93	13.93	14.92	15.92
	sq.	5.06	6.32	7.59	8.85	10.12	11.38	12.65	13.91	15.18	16.44	17.71	18.97	20.24
1 1-4"	dia.	4.91	6.14	7.37	9.60	9.82	11.04	12.27	13.49	14.72	15.95	17.17	18.40	19.63
	sq.	6.85	7.81	9.38	10.94	12.50	14.06	15.63	17.19	18.75	20.31	21.88	23.44	25.00
1 3-8"	dia.	5.04	7.42	8.91	10.30	11.88	13.36	14.85	16.33	17.82	19.30	20.79	22.27	24.76
	sq.	7.56	9.45	11.34	13.23	15.12	17.01	18.90	20.89	22.69	24.58	26.47	28.36	30.25
1 1-2"	dia.	7.07	8.84	10.60	12.37	14.14	15.90	17.67	19.44	21.20	22.97	24.74	26.50	28.27
	sq.	9.00	11.25	13.50	15.75	18.00	20.25	22.50	24.75	27.00	29.25	31.50	33.75	36.00

Table for Hooped Column Reinforcement

DIAMETER OF ENCLOSED CONCRETE	SECTIONAL AREA HOOPING	MAXIMUM PITCH	LENGTH OF HOOPING IN 1 FT. IN HEIGHT
6 inches	.0187 sq. inches	1¼ inches	183 inches
7 "	.0262 " "	1½ "	178 "
8 "	.0350 " "	1¾ "	174 "
9 "	.0450 " "	2 "	171 "
10 "	.0500 " "	2 "	190 "
11 "	.0619 " "	2¼ "	186 "
12 "	.0750 " "	2½ "	183 "
13 "	.0894 " "	2¾ "	180 "
14 "	.1050 " "	3 "	177 "
15 "	.1219 " "	3¼ "	175 "
16 "	.1400 " "	3½ "	174 "
17 "	.1594 " "	3¾ "	172 "
18 "	.1800 " "	4 "	171 "
19 "	.1900 " "	4 "	181 "
20 "	.2125 " "	4¼ "	179 "
21 "	.2362 " "	4½ "	177 "
22 "	.2612 " "	4¾ "	176 "
23 "	.2875 " "	5 "	175 "
24 "	.3150 " "	5¼ "	174 "
25 "	.3437 " "	5½ "	173 "
26 "	.3737 " "	5¾ "	172 "
27 "	.4050 " "	6 "	171 "
28 "	.4375 " "	6¼ "	170 "
29 "	.4712 " "	6½ "	170 "
30 "	.5062 " "	6¾ "	169 "

Material Required for One Cu. Yd. Concrete

PROPORTIONS OF MIXTURE			BASED ON 1" STONE		
CEM.	SAND	STONE	BBL'S CEM.	CU. YDS. SAND	CU. YDS. STONE
1	1 1-2	3	1.99	0.42	0.84
1	2	4	1.58	0.44	0.89
1	2 1-2	5	1.29	0.46	0.91
1	3	6	1.11	0.47	0.94

Material Required for One Bbl. Cement

PROPORTIONS OF MIXTURE			BASED ON 1" STONE			CU. FT. CONC. TO BBL. CEMENT	SIZE OF GAUGE BOXES	
CEM.	SAND	STONE	BBL'S CEM.	CU. YDS. SAND	CU. YDS. STONE		SAND	STONE
1	1 1-2	3	1	0.21	0.42	13 1-2	3'x6'x3 3-4"	3'x6'x 7 1-2"
1	2	4	1	0.28	0.56	17	3'x6'x5 1-16"	3'x6'x10 1-8"
1	2 1-2	5	1	0.35	0.70	21	3'x6'x6 5-16"	3'x6'x12 5-8"
1	3	6	1	0.42	0.84	24 1-3	3'x6'x7 1-2"	3'x6'x15"

NOTES.—One bag cement weighing .95 lbs. = .95 cu. ft. in volume. Four bags cement = 3.8 cu. ft. = 1 bbl.
For footings, heavy foundation walls, heavy machine foundations and similar work use 1–3–6 mix.
For piers, light foundation walls, light machine foundations and similar work use 1–2½–5 mix.
For reinforced concrete girders, beams, slabs, and thin walls use 1–2–4 mix.
For reinforced concrete columns use 1–1½–3 mix.

Design of Slabs

Directions for using Chart No. 1.* — Determine load to be carried, and span in feet. Follow vertically from span at bottom of chart for $M = wl^2 \div 10$, or from top of chart for $M = wl^2 \div 12$, to curved line representing bending moment in foot-pounds due to load assumed, thence horizontally to columns at left of chart, where thickness of slab, and sectional area of steel per foot in width of slab, will be found. From sectional area of steel determine the spacing of rods of type of fabricated metal from the table showing "spacing and sectional area of reinforcement for slabs 1 foot in width."

Example. — Assume combined live and dead loads at 250 pounds per square foot. Assume span of 10 feet over three or more spans, which would allow $wl^2 \div 12$ to be used. Follow vertically downward from figure 10 to line marked "250 pounds per square foot, $M = wl^2 \div 12$," thence horizontally to right, where it is found that a 5½-inch slab with .40 square inch of steel per foot in width of slab is required; or a 6-inch slab with .36 square inch of steel; or a 6½-inch slab with .325 square inch of steel, etc.

As the largest area of steel shown by the chart gives the most economical combination, the 5½-inch slab with .40 square inch of steel should be adopted.

To determine spacing of rods consult table for spacing, and there it will be found that 7/16-inch round rods, 4½ inches on centers, or ½-inch round rods, 6 inches on centers, or ½-inch square rods, 7½ inches on centers, or various other sizes or spacings can be used for the .40 square inch per foot in width.

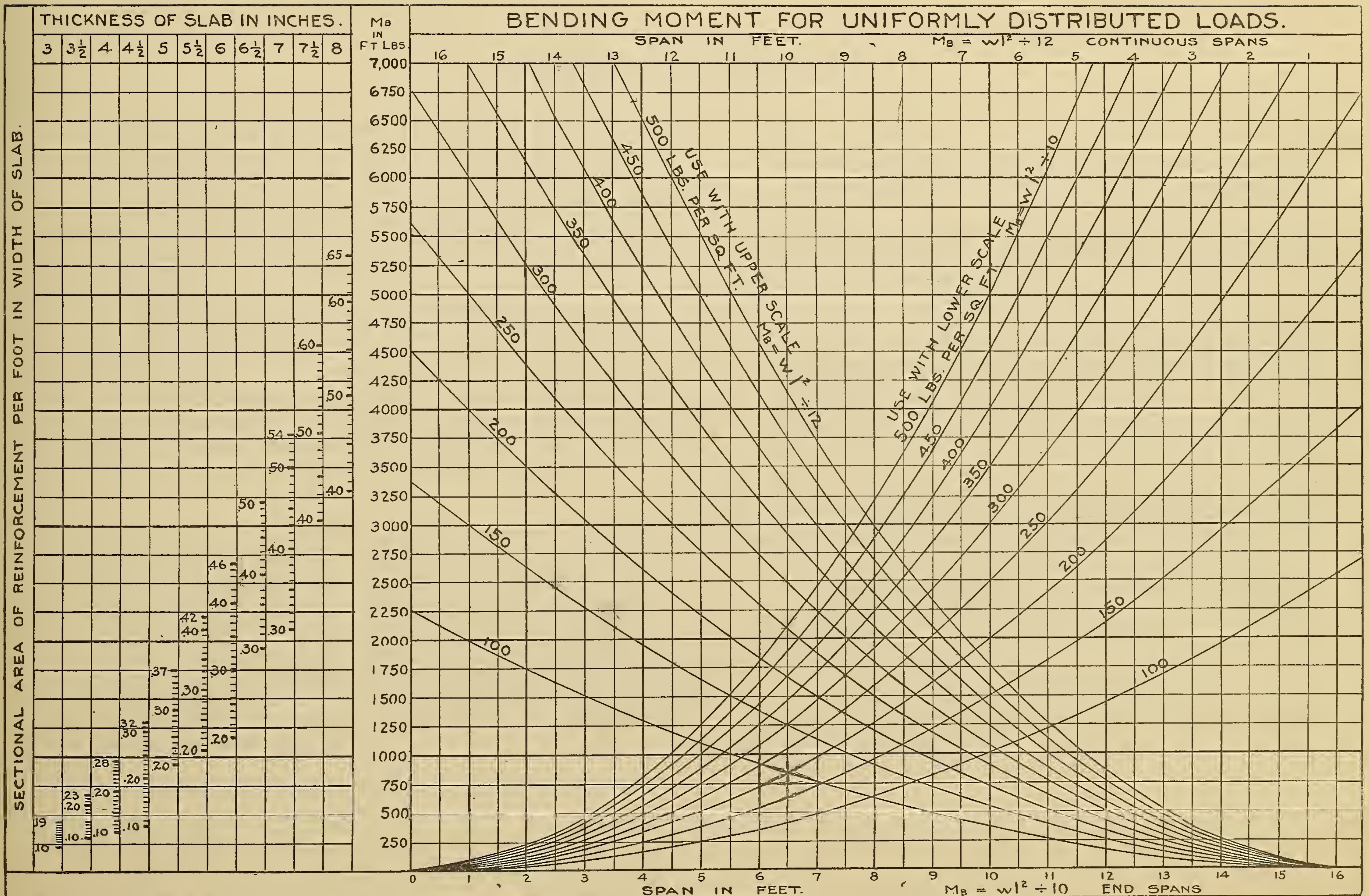
It also shows that a 3-inch No. 6 Standard Expanded Metal gives the requisite sectional area of steel.

Weight of Concrete Slabs per sq. ft.

Thickness; inches.....	3	3½	4	4½	5	5½	6	6½	7	7½	8
Weight; pounds......	37	44	50	56	62	69	75	81	87	94	100

*Chart No. I is to be used for determining thickness of and amount of reinforcement required in concrete slabs for any load and span within limits given.

CHART NO. I
REINFORCED CONCRETE SLABS



Design of T-Beams

Directions for using Charts Nos. II A and II B.*—Determine load to be carried per lineal foot of beam, and span in feet. Follow vertically from span assumed on chart II A for $M = wl^2 \div 10$, or on II B for $M = wl^2 \div 12$ to straight line giving shear due to load assumed, thence to right, where will be found the "Effective Web Area" required, also sectional area of vertical steel in a length equal to the effective depth (*i.e.*, the distance between the center of compression in the concrete and the center of tension in steel $= \frac{7}{8}$ d.)

After determining effective web area, return to span at bottom of chart, and follow vertically to curved line representing bending moment due to load assumed, thence to left to column where effective web area does not exceed the area previously determined.

From this column take the depth of beam, the width of stem being found at the top of the column. Opposite the depth in column marked "S" will be found the requisite sectional area of steel throughout bottom of beam, and over supports, for the distance shown in cut.

Example. — Assume combined live and dead load of 2400 pounds per lineal foot. Assume span of 20 feet. For intermediate spans use chart II B. Follow vertically from figure 20 at top of this chart to straight line marked "2400 pounds per lineal foot," thence to right, where it is found that an effective web area of 200 square inches and a sectional area of vertical steel of 1 square inch are required. Then from figure 20 at bottom of chart follow vertically to curved line marked "2400 pounds per lineal foot" $MB = wl^2 \div 12$, thence to left, where it is found that a beam 12 inches x $21\frac{1}{2}$ inches with 4.38 square inches steel is required. An equal area of steel is to be used at center of span and over supports.

*Charts Nos. II A and II B are to be used for determining the dimensions of and the amount of reinforcement required in concrete T-beams for any load and any span within limits given.

The effective depth of this beam is $\frac{7}{8}$ ($21\frac{1}{2}$ inches $-$ $2\frac{1}{2}$ inches) $=$ 19 inches.

The 4.38 square inches of tension steel can be made up by using two $\frac{1}{4}$-inch and one $1\frac{1}{8}$-inch square rods with a combined sectional area of 4.39 square inches.

If $\frac{3}{16}$-inch x 1-inch stirrups are used with a sectional area of .187 square inch for each of a pair of upright prongs, then the spacing of the stirrups for maximum shear would be

$$\frac{.187 \times 2}{100} \times 19 = 7.1 \text{ inches.}$$

The stirrups are to be continued with spacing in proportion to intensity of shear to a point where shear is not over 40 pounds per square inch in effective web area.

For end spans use chart II A in a similar manner.

Cuts Nos. 2 and 3 show a method of complying with the requirements.

Rectangular Beams. — Where it is necessary to use a beam of rectangular section, the sectional area of steel in tension should not exceed .77 of 1 per cent of the area of the concrete above the center of the steel.

Let f_s = unit stress in steel, or 16,000

d = distance between top of slab and center of steel in inches

b = breadth of beam in inches

Then Moment of Resistance in foot-pounds, where .77 of 1 per cent of steel is used

$$= \frac{7}{8} \frac{(.0077\, f_s \times bd^2)}{12} = 9\, bd^2, \text{ approximately.}$$

If less steel is used, the Moment of Resistance will be in direct proportion to the amount of steel.

CHART NO. II A

REINFORCED CONCRETE T-BEAMS

NOTE.—Use for end spans, and spans over one or two bays

DIMENSIONS OF T-BEAMS

6" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
15	66	1.44
14	60	1.32
13	55	1.21
12	50	1.09
11	44	.98
10	39	.86
9	34	.75
8	29	.63

7" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
18	95	2.08
17	89	1.95
16	83	1.81
15	77	1.68
14	70	1.55
13	64	1.41
12	58	1.28
11	52	1.14
10	46	1.01
9	40	.87

8" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
20	122	2.69
19	115	2.53
18	109	2.38
17	102	2.23
16	95	2.07
15	88	1.92
14	81	1.77
13	74	1.61
12	67	1.46
11	60	1.31
10	53	1.15

10" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
24	188	4.13
23	179	3.94
22	171	3.74
21	162	3.55
20	153	3.36
19	144	3.17
18	136	2.98
17	127	2.78
16	118	2.59
15	109	2.40
14	101	2.21
13	92	2.02
12	83	1.82

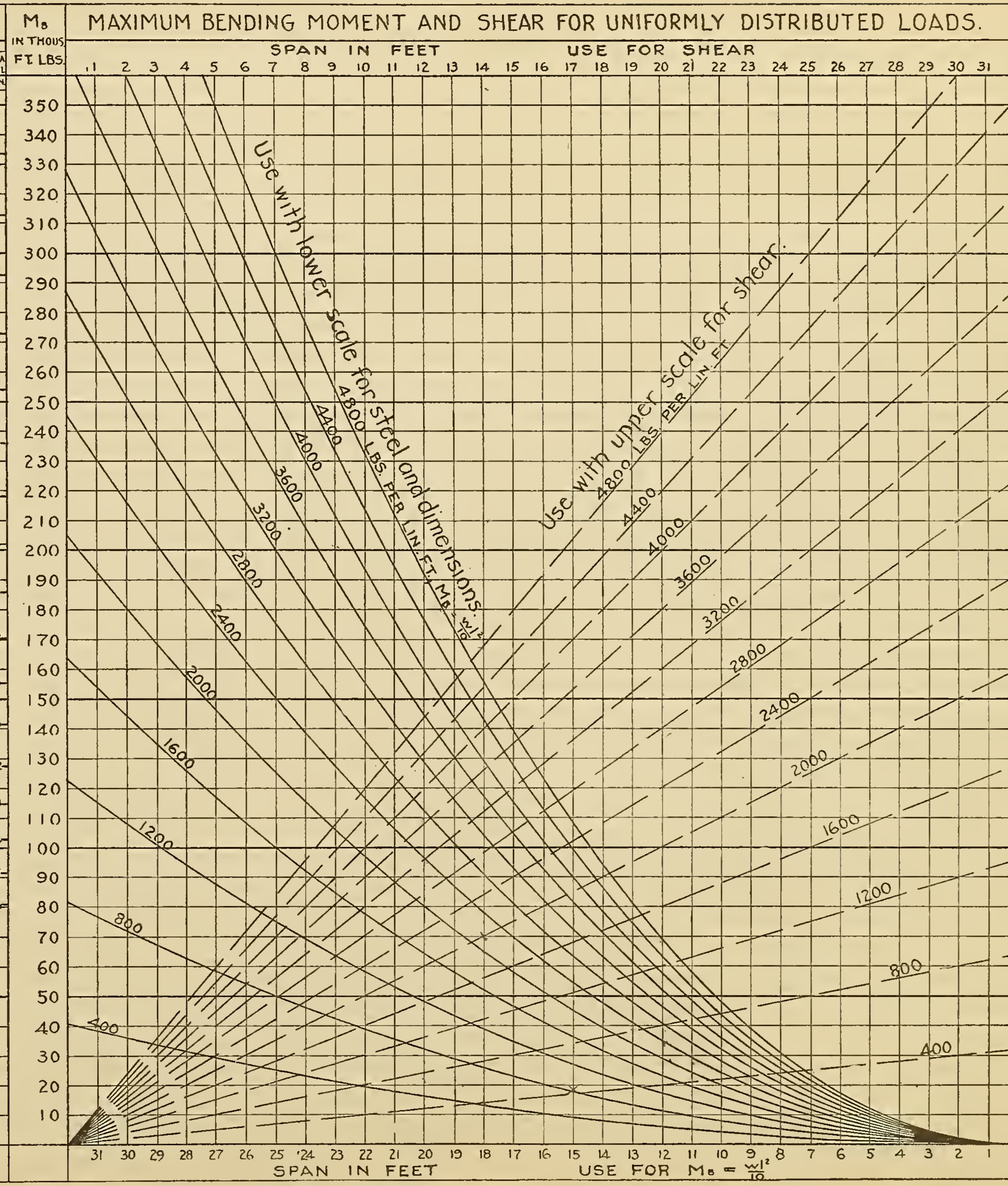
12" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
†30	289	6.34
*29	278	6.11
*28	268	5.88
*27	257	5.65
26	247	5.41
25	236	5.18
24	226	4.95
23	215	4.72
22	205	4.49
21	194	4.26
20	184	4.03
19	173	3.80
18	163	3.57
17	152	3.34
16	142	3.11
15	131	2.88
14	121	2.65

15" WIDE

DEPTH IN	WEB AREA SQ IN	AREA STEEL SQ IN
**35	427	9.36
**34	414	9.07
¶33	400	8.78
¶32	387	8.50
§31	374	8.21
§30	361	7.92
§29	348	7.63
‡28	334	7.34
‡27	321	7.06
‡26	308	6.77
†25	295	6.48
†24	282	6.19
†23	269	5.90
*22	256	5.62
*21	243	5.33
*20	230	5.04
19	217	4.75
18	204	4.46

MAXIMUM BENDING MOMENT AND SHEAR FOR UNIFORMLY DISTRIBUTED LOADS.



SHEAR IN THOUS. LBS.	EFFECTIVE WEB AREA	SHEAR REINFORCEM'T
70	583	2.92
68	567	2.83
66	550	2.75
64	533	2.67
62	517	2.58
60	500	2.50
58	483	2.42
56	467	2.33
54	450	2.25
52	433	2.17
50	417	2.08
48	400	2.00
46	383	1.92
44	367	1.83
42	350	1.75
40	333	1.67
38	317	1.58
36	300	1.50
34	283	1.42
32	267	1.33
30	250	1.25
28	233	1.17
26	217	1.08
24	200	1.00
22	183	.92
20	167	.83
18	150	.75
16	133	.67
14	117	.58
12	100	.50
10	83	.42
8	67	.33
6	50	.25
4	33	.17
2	17	.08

NOTE.—*Flange of beam must be at least 4 inches thick. †Flange of beam must be at least 4½ inches thick. ‡Flange of beam must be at least 5 inches thick. §Flange of beam must be at least 5½ inches thick. ¶Flange of beam must be at least 6 inches thick. **Flange of beam must be at least 6½ inches thick.

CHART NO. IIB

REINFORCED CONCRETE T-BEAMS

NOTE.—Use for continuous spans over three or more bays.

DIMENSIONS OF T-BEAMS.

6" WIDE Depth In.	6" WIDE Web Area Sq. In.	6" WIDE Area Steel Sq. In.
15	66	1.20
14	60	1.10
13	55	1.01
12	50	.91
11	44	.82
10	39	.72
9	34	.62
8	29	.53

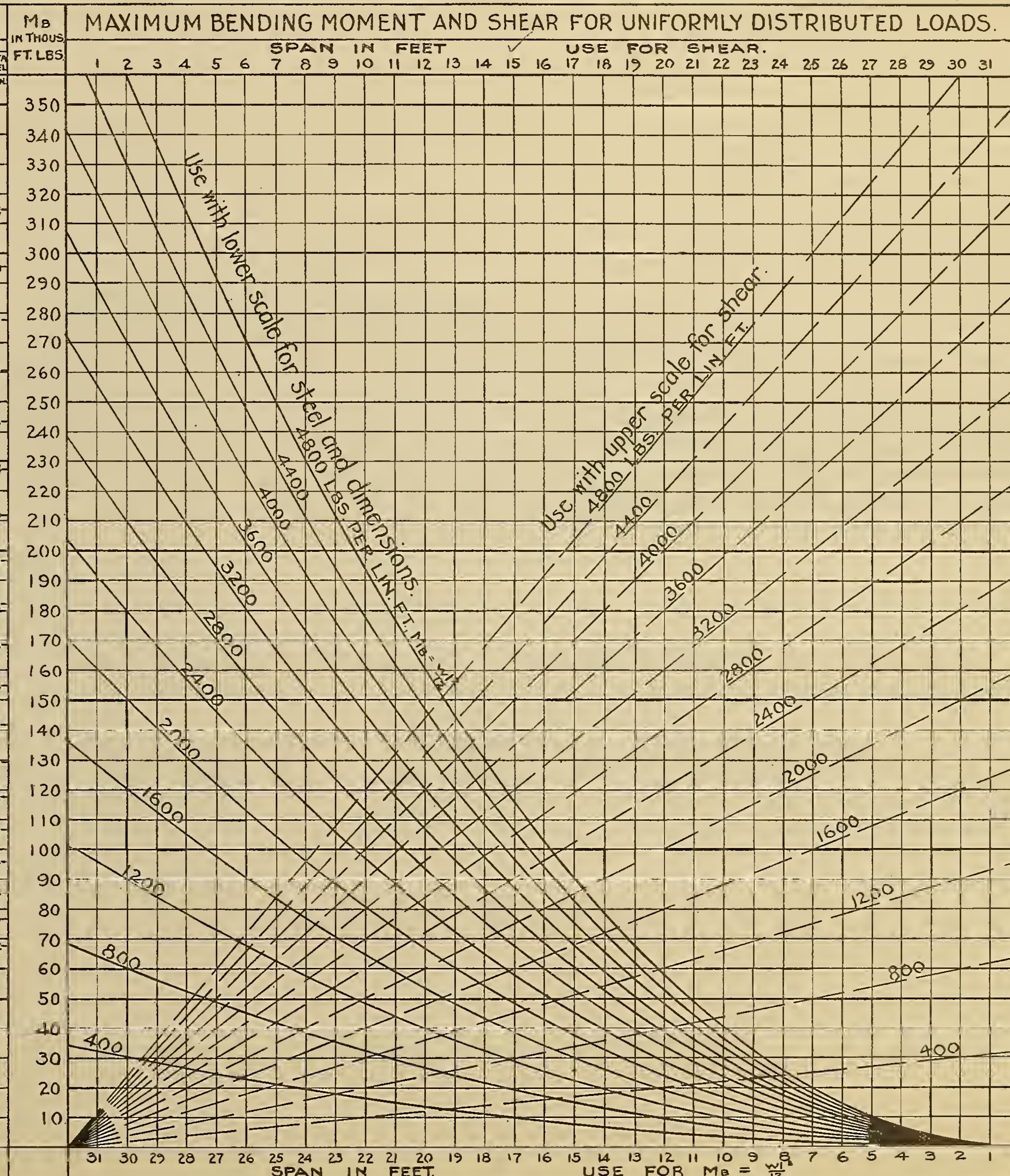
7" WIDE Depth In.	7" WIDE Web Area Sq. In.	7" WIDE Area Steel Sq. In.
18	95	1.74
17	89	1.62
16	83	1.51
15	77	1.40
14	70	1.29
13	64	1.18
12	58	1.06
11	52	.95
10	46	.84
9	40	.73

8" WIDE Depth In.	8" WIDE Web Area Sq. In.	8" WIDE Area Steel Sq. In.
20	122	2.24
19	115	2.11
18	109	1.98
17	102	1.86
16	95	1.73
15	88	1.60
14	81	1.47
13	74	1.34
12	67	1.22
11	60	1.09
10	53	.96

10" WIDE Depth In.	10" WIDE Web Area Sq. In.	10" WIDE Area Steel Sq. In.
24	188	3.44
23	179	3.28
22	171	3.12
21	162	2.96
20	153	2.80
19	144	2.64
18	136	2.48
17	127	2.32
16	118	2.16
15	109	2.00
14	101	1.84
13	92	1.68
12	83	1.52

12" WIDE Depth In.	12" WIDE Web Area Sq. In.	12" WIDE Area Steel Sq. In.
30	289	5.28
29	278	5.09
28	268	4.90
27	257	4.71
26	247	4.52
25	236	4.33
24	226	4.13
23	215	3.94
22	205	3.75
21	194	3.56
20	184	3.36
19	173	3.17
18	163	2.98
17	152	2.78
16	142	2.59
15	131	2.40
14	121	2.21

15" WIDE Depth In.	15" WIDE Web Area Sq. In.	15" WIDE Area Steel Sq. In.
‡36	440	8.04
‡35	427	7.80
†34	414	7.56
†33	400	7.32
†32	387	7.08
*31	374	6.84
*30	361	6.60
*29	348	6.36
*28	334	6.12
27	321	5.88
26	308	5.64
25	295	5.40
24	282	5.16
23	269	4.92
22	256	4.68
21	243	4.44
20	230	4.20
19	217	3.96
18	204	3.72



Shear in Thous. Lbs.	Effective Web Area	Shear Reinforcement
70	583	2.92
68	567	2.83
66	550	2.75
64	533	2.67
62	517	2.58
60	500	2.50
58	483	2.42
56	467	2.33
54	450	2.25
52	433	2.17
50	417	2.08
48	400	2.00
46	383	1.92
44	367	1.83
42	350	1.75
40	333	1.67
38	317	1.58
36	300	1.50
34	283	1.42
32	267	1.33
30	250	1.25
28	233	1.17
26	217	1.08
24	200	1.00
22	183	.92
20	167	.83
18	150	.75
16	133	.67
14	117	.58
12	100	.50
10	83	.42
8	67	.33
6	50	.25
4	33	.17
2	17	.08

NOTE.—*Flange of beam must be at least 4 inches thick. †Flange of beam must be at least 4½ inches thick. ‡Flange of beam must be at least 5 inches thick.

Design of Columns

Directions for using Chart No. III.* — Determine load to be carried, determine mixture of concrete, percentage of steel and type of column to be used. Follow vertically from load at bottom of chart to curves for 1:2:4 concrete, or from load at top of chart to curves for 1:1½:3 concrete, thence horizontally to right, where dimensions of column and amount of reinforcement are given.

Example. — Assume load of 400,000 pounds to be carried on a column composed of 1:2:4 concrete with 3 per cent longitudinal steel. Follow vertically from figure 400 at bottom of chart to curve marked "1:2:4 concrete, 3 per cent steel," thence to right to columns marked "A," where it is found that a column 25 inches square, 28¼ inches diameter or 27½ inches octagonal, reinforced with about 18.75 square inches steel is required. Add 3 inches to side or diameter of column to allow for protective covering.

Or assume this load to be carried on a hooped column composed of 1:1½:3 concrete with 3 per cent vertical reinforcement. Follow vertically from figure 400 at top of chart to curve marked "1:1½:3 concrete, 3 per cent steel," thence to right to columns marked "C," where it is found that a column 21¼ inches diameter reinforced with 10.5 square inches steel is required.

By referring to table for number and size of rods corresponding to sectional area, it is found that 18.75 square inches will require twelve 1¼-inch square rods, and 10.5 square inches will require six 1½-inch diameter rods; or such other combinations can be made as are desirable.

By referring to tables for amount of hooped reinforcement, the size and spacing of hooping is found.

Hooped Reinforcement. — Based on 1 per cent of volume of enclosed concrete.

Let D = diameter of enclosed concrete

A_h = sectional area of one strand of hooping for maximum pitch

P = maximum pitch allowable

h = length of hooping in 1 foot in height of column

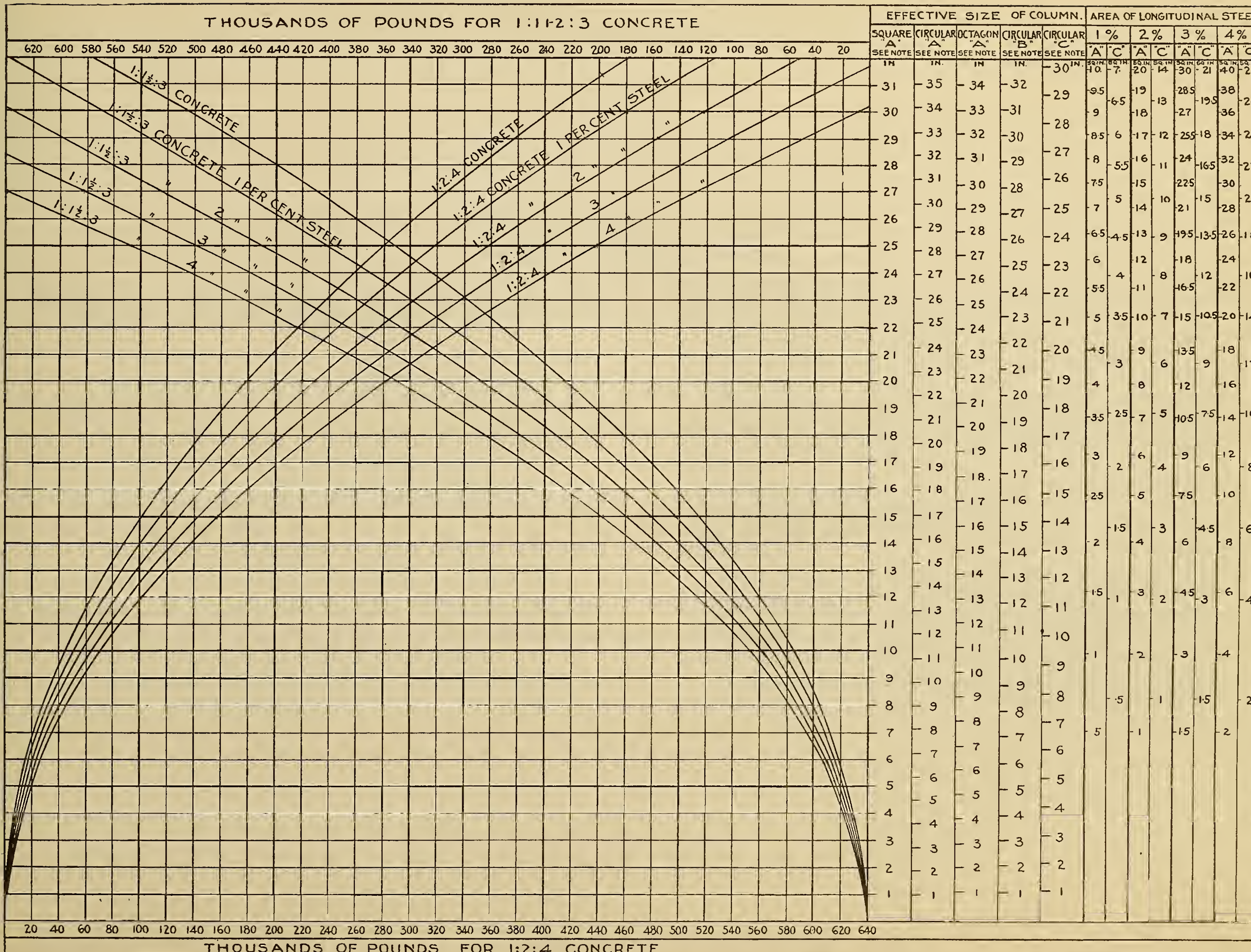
Formulas:—$A_h = .0025\ PD$; $h = .38\ D \div P$.

If rods of sectional area less than A_h are used, then the pitch may be decreased in direct ratio, and the length h increased in inverse ratio.

*Chart No. III is to be used for determining the dimensions of, and the amount of reinforcement required in, concrete columns of different designs and shapes as shown, for any load within limits given.

CHART NO. III

PLAIN AND REINFORCED CONCRETE COLUMNS



NOTE.—"A" refers to columns without hooping, "B" to columns without longitudinal reinforcement, and "C" to hooped columns with vertical reinforcement.

Cost of Materials

Directions for using Chart No. IV.—The chart gives the cost of concrete of the various mixtures shown when unit prices of materials are known.

The four upper lines give the cost per cubic yard, the intermediate line the cost per 100 square feet of granolithic surface 1 inch thick, and the lower lines the cost of 10 square feet of slabs or walls of concrete up to 12 inches in thickness.

The upper line of figures at the bottom of the chart indicates the cost per cubic yard of stone, sand or per barrel of cement.

The lower line represents the cost per ton of stone or sand corresponding to the yard price, based upon the assumption that a yard of stone or sand weighs 2700 pounds.

The table gives the quantities of material required by the various proportions of mixtures and sizes of gauge boxes to measure them.

Examples.—Examples showing use of chart. To determine cost of materials in 1 cubic yard 1:2:4 concrete, assuming the cost of stone as $1.40 per ton; sand $1.20 per yard; and cement $1.45 per barrel:—

Cost of stone. Follow vertically from 1.40 in lower space to line designated "cost per cubic yard 1:2:4 concrete," thence horizontally to first column at right, where it is found that $1.64 is the cost of the stone.

Cost of sand. Follow vertically from 1.20 in upper space to same line, thence to second column at right, where it is found that $0.53 is the cost of the sand.

Cost of cement. Follow vertically from halfway between 1.40 and 1.50 in upper space to same line, thence to right to fifth column, designated "cost of cement 1:2:4," where it is found that $2.39 is the cost of the cement.

Total cost of material for one yard of 1:2:4 concrete:—stone $1.64, sand $0.53, cement $2.30, total $4.47.

To determine cost of materials in 100 square feet of 1 inch granolithic surface:—

Assume unit price on stone, sand and cement the same as before. Start from same figures as before and follow vertically to line representing cost of granolithic surface, thence to first, second and last columns, where it is found that the stone costs $0.82, the sand $0.27 and the cement $1.95, making a total cost for materials for the 100 square feet of $3.04.

To determine the cost of 10 square feet of slab or wall of any thickness up to 12 inches apply the same methods as described in the preceding cases.

CHART NO. IV

COST OF CONCRETE MATERIALS (not including labor)